Factors of Comprehensibility of Airline Safety Briefing Cards: An Eye-tracking Study

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Abstract

In civil aviation, passengers' comprehension of cabin safety information could guide their evacuation when facing emergency (Hsu, 2010). For this reason, it is of great significance to improve the comprehensibility of airline safety briefing cards. This study created a new mixture presentation style of briefing pictorials, which employed real pictures of crucial equipment mixed with illustrations of irrelevant backgrounds, and conducted a comparative study with two exist illustration and real picture styles. When set independent variables as pictorial realism (all-real, all-illustration, and mixture), we compared users' eye-movement patterns, operating performances and subjective usability evaluation of pictorials in those three conditions. The result showed that, the mixture style could efficiently decrease the attention distraction caused by irrelevant details, and help passengers performing well in emergency manipulations. The study proved that the brand new design could truly improve the comprehensibility of airline safety briefing cards, and be well accepted by passengers.

Key words: safety briefing, usability test, eye-tracking

Introduction

In the aviation safety area, cabin safety information is of great importance in passengers' safety protection. Therefore, how to inform passengers with safety information correctly and efficiently is of main concerns among industry (National Transportation Safety Board, 1974; Transport Canada, 2001; Australian Transport Safety Bureau, 2006). Although the channel of cabin safety information communication varies, including videos and live demonstrations, briefing cards are still widely used and required by regulations due to their low cost and repeated readability (Muir & Thomas, 2004). According to civil aviation authorities' document (for instance FAA 121-24C), airlines must provide safety cards to inform passengers of cabin safety information and behavioral routines on board transport airplanes (Federal Aviation Administration, 2003).

Safety briefing cards usually present information graphically, using pictures, illustrations, and few text to demonstrate emergency safety procedures to passengers. However, plenty of studies proposed that the current briefing cards pictorials rarely play their due roles, which means passengers can hardly understand the content of them (Caird, Wheat, McIntosh, & Dewar, 1997; Fennell & Muir, 1992; Hsu, 2010; Molesworth, 2014). Fennell and Muir (1992) employed a mockup operation test to measure passengers' comprehension of safety briefing cards. Result showed that 46% of participants were not able to find and take out the life vests from packages correctly. Over 50% participants had trouble answering questions about the oxygen mask usage. Only 8% participants could detailed describe the procedure of opening safety doors. Caird et al. (1997) found that the comprehensibility of most safety briefing pictorials was extremely low, especially the information about emergency excavation. Hsu (2010) used questionnaires to investigate the comprehension of safety briefing cards in Chinese context. The result indicated the comprehension of test pictorials didn't meet NTSB minimum standard, and the worst performance occurred within the information about evacuation, brace position, and life vest usage. Molesworth (2014) verified that when a safety briefing contained 34 to 41 crucial points, less than half of them could be memorized correctly by passengers. Furthermore, the design defects of briefing pictorials caused the difficulties in conducting emergency procedure for passengers in real environments. For example, many of the survivors pointed that their excavation was not affected by the presented safety briefing cards (NTSB, 1983).

Researchers reached a consensus that one strategy to increase the effectiveness of safety briefing cards is to improve the comprehensibility (Corbett, McLean, & Cosper, 2008) and interest (FAA, 2003; Seneviratne, & Molesworth, 2015), making passengers to pay more attention on briefings. Several research focused on the influence of pictorial realism on content comprehension (Dwyer, 1967; Johnson, 1980). Johnson's study (1980) showed that, comparing with real pictures, illustrations are easier to understand by passengers on safety cards. Because illustration could accelerate the identification of important details by emphasizing crucial elements, making it outstanding from irrelevant details. Dwyer (1967) found it is unnecessary to provide excessive realistic details to student when presenting visual information. Because excesses of realism may interfere with the transmission of information, in many cases, the reduction of realistic details in an illustration improve the instructional effectiveness of it.

But, the deviation between illustrations and real situations may harm the scene cognition of individuals in the operation (Glenberg & Langston, 1992; Schmidt & Kysor, 1987). When the instructional texts were presented with corresponding pictures illustrating the manipulation order, people tended to mentally represent the procedure (Glenberg & Langston, 1992). In order words, pictures help users to build the mental models of manipulation procedures. The safety card comprehensibility can be improved significantly by providing more realistic pictures and more logic steps in the guideline (Schmidt & Kysor, 1987). Thus, excessively abstract illustrations will damage the human information processing in developing correct psychological representations, and increase the error rate of user's operation. For example, passengers may have trouble in matching the location of life vests in the illustrations and the real environment.

Previous empirical studies mainly focused on integrated realism of pictorials, ignoring the realism variation within different objects. In order to combine the concise of illustrations and the matching superiority of pictures, we created a mixture presentation style. The mixture pictorial employs real pictures of crucial operating items and illustrations of irrelevant backgrounds. This new presentation style not only helps passengers to match the equipment between pictorials and realities, but also reduce the distraction from details.

Research methods involved in safety cards comprehension studies include focus group (ATSB, 2004), open-end questions (Corbett, McLean, & Cosper, 2008; Silver & Perlotto, 1997), rating scales (Hsu, 2010), and mockup operation tests (Fennell & Muir, 1992) etc. Recently, many researchers employed eye-tracking technique to further understand the mechanism of pictorial comprehension (Hsu, Li, & Tang, 2013; Seneviratne, & Molesworth, 2015). Hsu and his colleagues (2013) confirmed that the comprehension of safety briefing pictorials is positively correlated with the fixation duration on objects. Then proposed it is crucial to make passengers pay more attention on the safety card to increase the comprehensibility. Our study will further investigate this issue by combining mockup operation tests and eye-tracking experiments, to study the influence of pictorial realism in the comprehension and attention distribution.

In the mockup operation test, we used thinking aloud and operational task rather than questionnaires to improve the ecological validity. A previous research (Yang, Yu, Richard Allen,

&Chen, 2013) found that participants could memorize more action commands in operation test than in oral recalling. Thus operating tasks may tell the comprehension of manipulation commands accurately and authentically. Based on this hypothesis, we built a mockup cabin environment with real emergency equipment to conduct the recall test, in which participants were required to conduct certain emergency procedure illustrated on the safety cards they had just read.

However, the operation performance cannot reveal the cognitive processing during the comprehension of safety card pictorials, such as attention distributions. Therefore, we employed eye-tracking technique to better understand how passengers read and comprehended safety cards. The eye-tracker can help us to quantitatively measure users' fixation rate of area of interests (AOI) and the total fixation time, then separate the attention distributions toward different objects. Besides, we assigned interviews and the System Usability Scale (SUS) to participants to obtain their subjective performances toward different design styles.

Method

Participants

A total of 36 participants (20 females) with an average age of 21.57 (SD=1.10) years were recruited from student population at Zhejiang University. 23 participants have flying experiences in the recent year, while other 13 do not. All participants have normal or correct to normal visual acuity, no color blindness or weakness. Participants were randomly divided into three groups: 11 in the all-real group, 11 in the all-illustration group, and 14 in the mixture group.

Pictorial Materials

Test pictorials were adapted from a currently used airline safety briefing card (A321, China Eastern Airlines) by ©Adobe Photoshop CS6 and a ©WACOM pen tablet. Materials were evaluated in a 5-member focus group (3 experienced passengers and 2 novice users of safety cards), and revised the contrast, brightness, hues and lines based on comments. Pictorials were redesigned into three presentation styles with different degrees of realism, Sample pictorials of different styles were shown as Figure 1.:

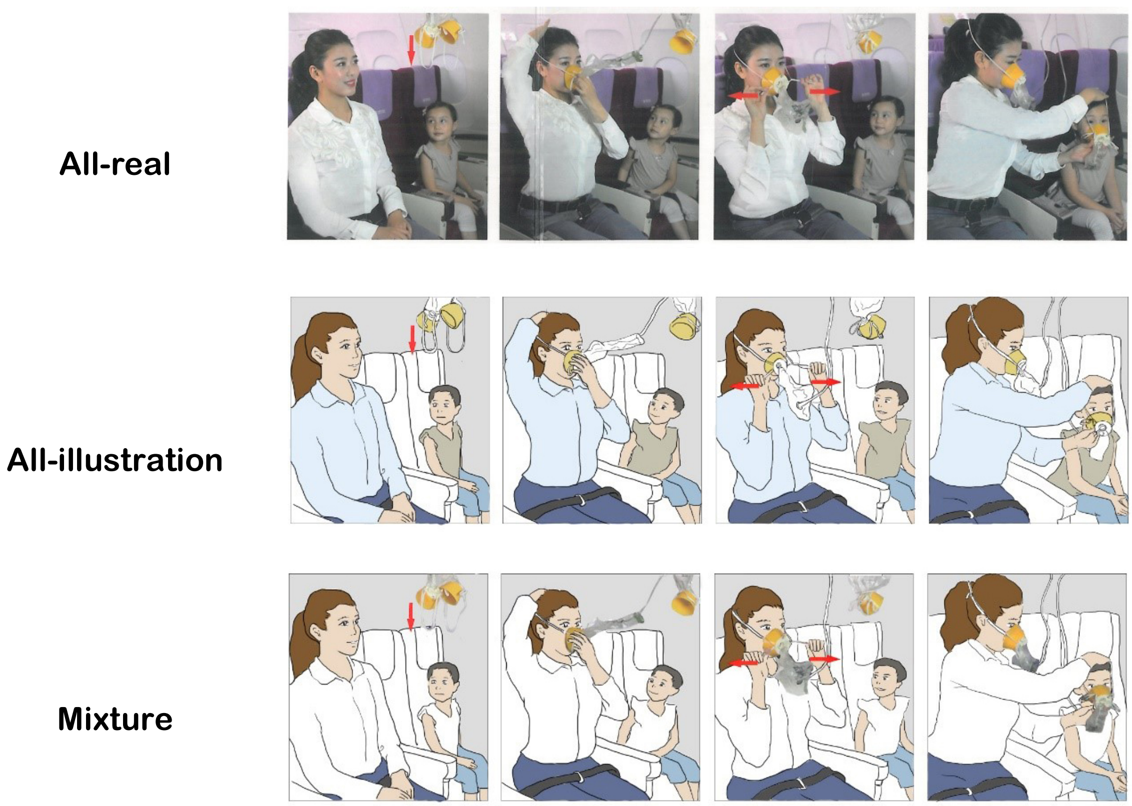

Figure 1. Sample safety briefing pictorials of three levels of realism

All-real style: Scanned a copy of the original safety briefing card, which used all real photos.

All-illustration style: Used the pen tablet to draw the outline of original pictorials, then filled appropriate colors in Photoshop CS6 (without texture or shadow).

Mixture style: Replaced the emergency operating items in the all-illustration style with real photos. Took "oxygen mask usage" as an example, the crucial items, oxygen masks were presented in real photos, while other elements were drawn in illustrations.

According to national regulations, a sample safety briefing card must contain following contents: (1) Pre-flight preparations, (2) Carry-on baggage, (3) Seatbelts, (4) Life vest, (5) Oxygen mask, (6) Brace position, (7) Emergency exist, (8) Land and water evacuation. Because information about the emergency evacuation is most important, yet has uniformly low comprehensibility, we selected "Life vest usage", " Oxygen mask usage" and "Safety door operations" as three target stimulus, while "Pre-flight preparations", "Carry-on baggage", "Seatbelts", "Brace position", and "Land and water evacuation" were five distracted stimuluses. Those contents were serially individually presented in the experiment to exclude irrelevant variables such as layout and text.

Other Materials and Equipment

Stimulus material were presented on a 1024×768 pixel CRT monitor positioning 65 cm away from participants. The eye-movements were recorded by a SMI Hi-speed 5000 eye-tracker with 500Hz sampling rate.

Priming video: The Movie clip of *Final Destination* was used for priming the anxiety and situation awareness of participants. The main scene was an aircraft collision, resulting violent cabin vibrations, decompression and passengers panic.

Emergency equipment: A life vest, an oxygen mask and the pictures of emergency exit corresponding with the pictorials safety card showed.

Questionnaires: A scale adapted from Brooke's (1996) System Usability Scale (SUS) in order to fit the airline safety cards usability test.

Design and Procedure

A between subject design with pictorial realism of three levels (all-real, all-illustration, and mixture) as independent variable was employed. The result of eye-tracking, mockup operation test, interviews as well as SUS featured as dependent variables.

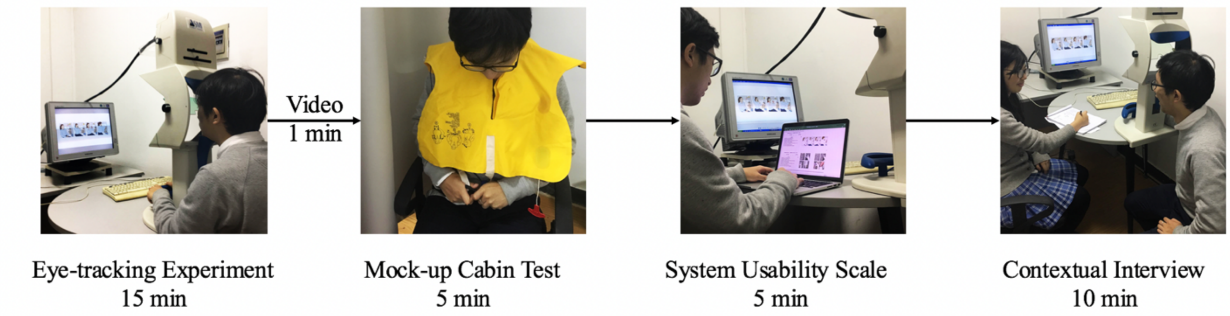

Figure 2. Experiment procedure

The experiment procedure is shown in *Figure 2*. Participants were first required to self-report their past flying experiences and familiarities of safety briefing cards (5-point Likert). After each participant adapted to the eye-tracker and passed the calibration process (9-point calibration with deviation less than 1 degree in both x and y axis), 3 target stimulus pictorials were serially presented in a random order, while other 5 distracted pictorials remained static (such as target 1*→"Pre-flight preparations"→"Seatbelts"→target 2*→"Carry-on baggage"→ "Brace position"→target 3*→ Land and water evacuation"). Participants could review each pictorial as long as they wanted, just like passengers on the plane. Considering the real situation in cabin safety information communication, participants were not told about the later recalling test, but noticed the importance of briefing cards.

After the eye-tracking explore, participants were presented the priming video, then assigned mockup operation test. During the operation task, participants were told to say whatever came into their mind as they complete the task including what they were looking at, thinking, doing, and feeling etc. (thinking aloud tech.) The test consisted of 3 scenes measuring the comprehension of different contents. "Oxygen mask usage" required participants to correctly put on a hanging mask in 15 secs. "Life vest usage" asked participants to locate and wear the vest in 2 mins, when the life vest was placed under the chair. In the "Safety door operations", participants were presented with a picture of an aircraft safety door, and required to oral recall the procedure of opening it. The aloud thinking and answers of participants were recorded. Two experimenters would rate the operation performance independently, and the standard was according to key points shown on pictorials. For example, putting on an oxygen mask consisted of three key points: (1) pull down the mask, (2) put it on, (3) adjust the lace. Since each key point was worth one score, participants' performance was measured by the total score.

Final phase was filling the SUS, which contained stimulus pictorials and relevant questions. Experimenters then assigned structured interviews to participants.

Results

Since the rations of experienced and novel passengers are equal among three groups, past experiences will not be analyzed in the following comparisons. This result section consists of three part: (1) analyze participants' attention distributions to safety briefing through eye-tracking record, (2) measure the comprehensibility of pictorials through operation test result, (3) verify the usability of safety cards through SUS.

Eye Movement Analysis

In order to discover the mechanism in comprehension and variations in attention distribution, we analyzed participants' eye-movement when watching safety briefing pictorials with different contents and realisms. The first fixation duration (FFD), fixation duration (FD), and fixation count (FC) were used. The duration time of participants' first look at the pictorial is defined as FFD. A long FFD reveal the difficulty in understanding or high interest in materials

(Goldberg & Kotval, 1999). The meaning of FD and FC should be explained combine with users' behavioral performance (Jacob & Karn, 2003; Just & Carpenter, 1976).

One-way Analysis of Variance (ANOVA) was conducted across pictorial realisms with different contents, the effect power η^2 was calculated in the method of Cohend (1977). Realism had no significant influence on FFD in "Oxygen mask usage" ($F(2,35) = 2.12$, $p = .136 > .05$, $\eta^2 = .11$), "Life vest usage" ($F(2,35) = 1.18$, $p = .319 > .05$, $\eta^2 = .07$), as well as "Safety door operations" ($F(2,35) = .91$, $p = .413 > .05$, $\eta^2 = .05$). The analysis of other two dependent variables appeared the same patterns, that there was no significant difference in FD and FC between realisms (all *ps* > .05). The results above showed that participants deliver consistent attentions to pictorials in different presentation styles. Changing the realism of pictorials on safety cards hardly influences users' global attitude towards pictorials.

However, there is an important variation within the attention distribution of different objects on the pictorial. We defined the area including crucial operation equipment and movements as AOIs, see Figure 3 for an example.

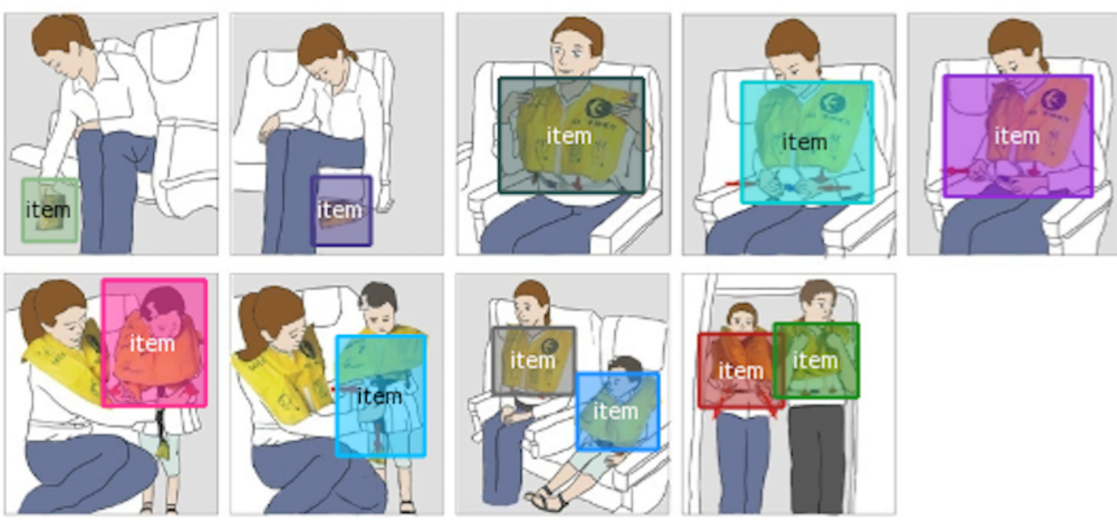

Figure 3. Crucial operation areas

We used the ratio of the FD (FC) in crucial operation area and the global FD (FC) as index to reveal users' selective attention toward emergency manipulations. ANOVA showed a significant difference of FD ratios across realisms in the "Oxygen mask usage" ($F(2,35) = 3.02$, $p = .063 < .10$, $\eta^2 = .15$), post hoc comparison-Bonferroni showed the ratio in the mixture group (51.6%±4.4%) is significant higher than it in the all-real group (34.1%±6.4%), $p = .084$. The significant difference across realisms were also found in the "Safety door operations" ($F(2,35) = 3.82$, $p = .032 < .05$, $\eta^2 = .19$). The post hoc comparison showed that the ratio of FD was significantly higher in the mixture group (56.5%±3.7%) than in the all-real group (40.3%±4.9%), $p = .034$ (See Figure 4.).

The same statistical analysis showed a similar tendency in the ration of fixation counts. A significant difference of FC ratios across realisms was found in the "Oxygen mask usage" ($F(2,35) = 4.14$, $p = .025 < .05$, $\eta^2 = .20$), post hoc comparison showed the ratio in the mixture group (55.5%±4.6%) is significant higher than it in the all-real group (33.4%±6.6%), $p = .028$. The significant difference across realisms were also found in the "Safety door operations" ($F(2,35) = 3.34$, $p = .048 < .05$, $\eta^2 = .17$). The post hoc comparison showed that the ratio of FD was significantly higher in the mixture group (60.7%±3.8%) than in the all-real group (43.4%±5.7%), $p = .048$ (See Figure 5.).

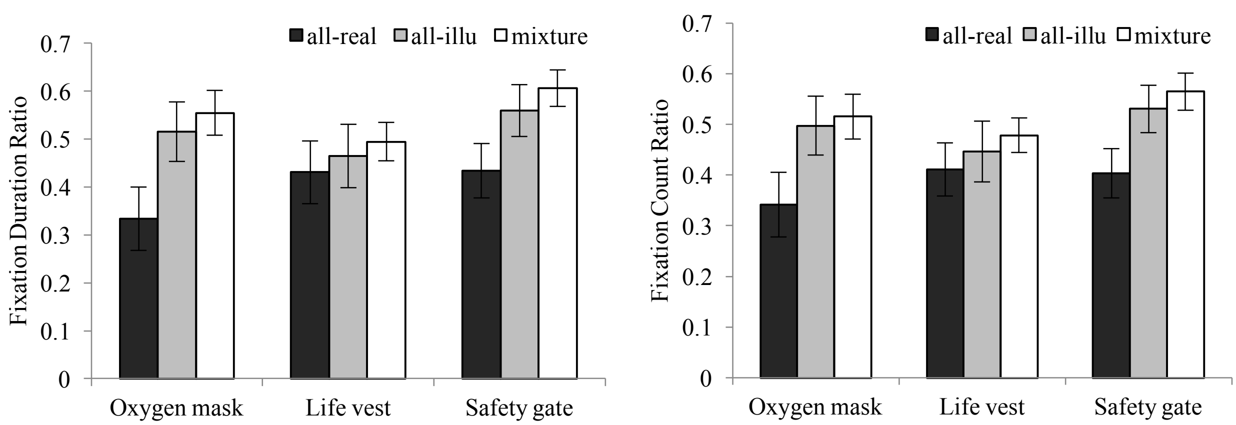

Figure 4. & 5. Ratios of FD & FC to crucial operation areas

A sample fixation time heatmap between three groups could directly reveal the different attention distributions, especially over the crucial operation areas (See Figure 6.). We found participants in the mixture group pay more attentions to area related to exit operations, such as the observation window and the safety door handle etc. The fact confirmed that the mixture design could reduce the distraction of irrelevant detail, focusing participants on the informative area, helping them better understand the emergency procedure, especially for the safety door and the oxygen mask.

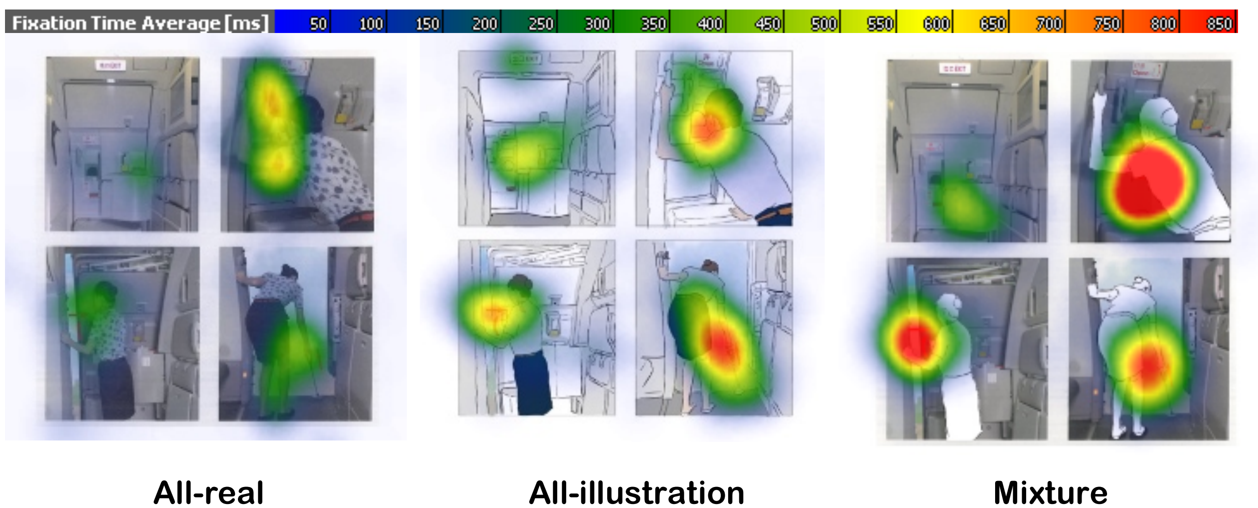

Figure 6. Fixation time heatmap of "Safety door operations"

Operation Test Analysis

Conducted normality test to operation task scores for three groups, shown that the scores of three operations were not normally distributed (Kolmogorov–Smirnov test, all *ps* < .05). Thus, the following analysis about participants' operation performance employed Kruskal-Wallis H test (See Table 2. and Figure 7.). The results indicate that:

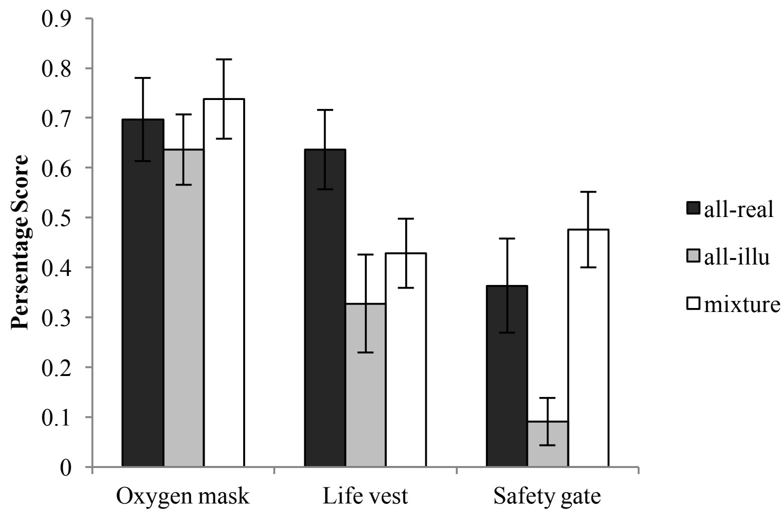

Figure 7. Performance scores in the operation tests

(1)"Oxygen mask usage"- scores rank as mixture > all-real > all-illustration, but no significant difference was found across pictorial realisms ($KW_c = 0.10 < \chi^2_{0.05}(2)$, $p > .05$).

(2)"Life vest"- scores rank as all-real > mixture > all-illustration, the significant differences were found were found between the different levels of realism($KW_c = 6.25 > \chi^2_{0.05}(2)$, $p = 0.044 < .05$, $\eta^2 = 0.18$). The post-hoc comparision showed that the significant difference was existed between all-real and all-illustration groups (p =0.049< .05).

(3)"Safety door operations"- scores rank as mixture > all-real > all-illustration, the significant differences were found were found across realisms ($KW_c = 11.92 > \chi^2_{0.05}(2)$, $p = 0.003 < .01$, $\eta^2 = 0.34$). The post-hoc comparision showed that the significant difference was existed between mixture and all-illustration groups ($p = 0.002 < 0.01$).

Table 1.

Performance scores in the operation tests (percentage scores)

Contents	All-real	All-illu	Mixture
Oxygen mask	0.61 ± 0.08	0.61 ± 0.06	0.70 ± 0.09
Life vest	0.63 ± 0.07	0.32 ± 0.09	0.38 ± 0.05
Safety door	0.38 ± 0.09	0.09 ± 0.04	0.52 ± 0.09

The analysis above indicated that participants who read all-illustration briefing cards performed worst in the operation tests. Other two groups' had better performances among three tasks. This fact confirmed the importance of objects matching between pictorials and real world, as well as users' mental model building. See detailed discussion in the next secession.

SUS Analysis

Conducted ANOVA to SUS scores for three groups (all-real, all-illustration, mixture). We found a significant difference between groups in "Oxygen mask usage" ($F(2,35) = 3.77$, $p = .034 < .05$, $\eta_p^2 = .19$). No significant difference was found in "Life vest usage" ($F(2,35) = 0.41$, $p > .05$, $\eta_p^2 = .02$) and "Safety door operations" ($F(2,35) = 1.53$, $p > .05$, $\eta_p^2 = .09$). See detail result in Table 3. and Figure 8.

Table 2.
SUS scores

Contents	All-real	All-illu	Mixture
Oxygen mask	79.8±5.9	58.4±6.6	63.6±4.2
Life vest	67.5±6.5	61.1±4.0	61.3±5.5
Safety door	41.6±4.8	29.1±6.6	33.2±3.5

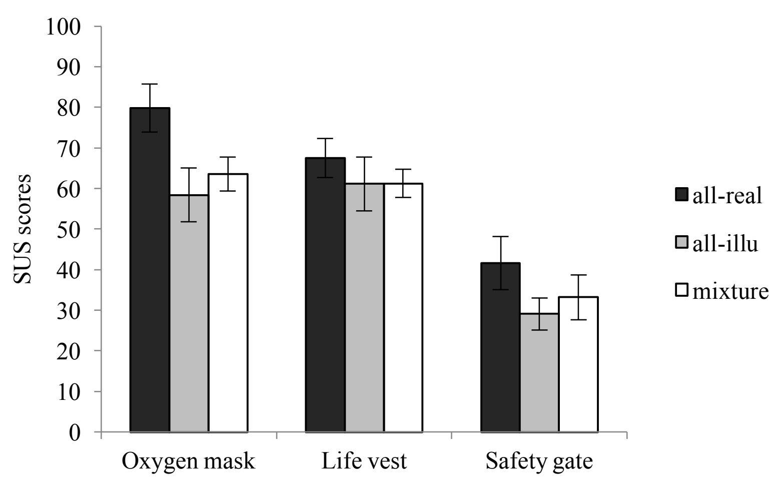

Figure 8. SUS scores for pictorials with different levels of realism

In order to discover users' subjective acceptance to different pictorials, we cited the Grade Scale standard (<50.9: unacceptable, 50.9-71.4: good, 71.4-85.5: excellent, Bangor, Kortu, & Miller, 2012) to evaluate the results of pictorial with different realism. Overall, all-real style had the best usability due to users' familiarity to this form. Mixture style also reached the "good" level, indicating that users can well accept the combination of 2-D illustrations and 3-D pictures. When the contents were "Oxygen mask usage" or "Life vest usage", the usability of three presentation styles all achieved good level. Considering the inferior position of "Safety door operations", we interviewed participants and found it was due to the logic loophole in layout. The operation procedure of opening a safety door was too complicated to present within few pictures.

Discussion

This study focused on the influence of pictorial realism on comprehensibility of airline safety briefing cards. Result showed that, the mixture design, the combination of real photos of operating items and illustrations of backgrounds, could efficiently decrease the distraction caused by irrelevant details, so that guide users to pay more attention on informative areas related to emergency operations. Eye-tracking record indicated a significant difference in fixation ratios between three pictorial realism levels (all-real, all-illustration, mixture). When the contents were "Safety door operations" or "Oxygen mask usage", participants in the mixture group had significant higher gaze ratios in the key informative areas compared with others in the all-real group. We believed the contrast between photos and illustrations in mixture design could serve as visual cues, so that encouraged participants to pay more attention on crucial objects. Besides, there was no significant difference in the global first fixation duration, total fixation duration, and total fixation count across different realism groups. Therefore, we assumed that, changing realism level of pictorials would not influence users' interests or comprehensions towards the whole page.

In this research, we creatively built a mock-up cabin environment to test the comprehensibility of different safety cards, in which participants were presented with scenarios describing aircraft accident and required to conduct appropriate operations. Two independent raters were involved in order to ensure the validity and objective of measurements. Operation tests showed that, participants who read the mixture safety cards had better performances in the safety door and oxygen mask operations. Based on interview results, we believed that, the photos of operating items could encourage users to build the correct mental model of emergency manipulations, so that help them perform well when in the real environment. For example, a participant supposed that the illustrations of safety door operations were too abstract. Thus it was hard for him to recall the position of handles or windows in memory when facing a real door. On the contrary, the real photo could help users to mentally rehearsal for operation procedure, which enabled them to finish the task successfully. It was confident for us to confirm the superiority of real pictures in the comprehension of safety briefing cards.

However, the pattern was different if the content was life vest. Participants in the all-real group had the best performance in operation tests, and no significant difference was found in fixation ratios between groups. Participants complained it's weird to see a life vest worn on a cartoon man, due to the large overlap of 2-D illustrations and 3-D photos. There was a large number of participants in mixture and all-illustration group could not correctly wear the life vest because of the wrong mental model. Actually, an aircraft life vest was more like a bib rather than a jacket (those using on the ship). We thought the mental model building was related to the stimulus materials. The missing of light and shadow feature in 2-D illustrations may cause difficulties in the perception of the relative position between body and vest, and then misled passengers' behaviors. How would the overlap and coverage between objects with different realisms influence the comprehensibility of mixture pictorials? This question should be answered in the further research.

In the usability test, no significant difference was found between mixture group and other two groups. All-illustration and mixture pictorials all reached the acceptable usability level, except "Safety door operations". According to the interviews, the obstacles to comprehension lay in storyboard and layout logic, rather than out topic, realism. In sum, the result of usability scale showed a positive attitude of passengers towards our new design. We believed the mixture of photos and illustrations is a worthwhile redesign.

Previous study about safety information communication usually employed methods including questionnaires and oral report. However, participants' correct answers did not guarantee their proper operation in real emergency situations. This study creatively used interdisciplinary research methods to test the comprehensibility of safety briefing cards, such as mock-up cabin tests, eye-tracking experiments, structural interviews and system usability scales, which provided an all-round perspective in this area and boost the ecological validity of our study. Besides, our research not only compared overall realism of pictorials, but also separately evaluate the realism of different objects. By doing this, we further investigated the impact of pictorial realism in visual attention and mental representation forming. As far as we were concerned, no previous study even conducted in this topic.

Besides, our new design was of great application value in industry. Considering the low attraction and intelligibility of current used airline safety briefing cards, we designed a new type of pictorial, mixing of real photo items and illustration backgrounds, to illustrate emergent manipulations to passengers. The experiment has confirmed its superiority in comprehensibility and operation instruction. Since passengers' comprehension of cabin safety information positively correlates with their chance of surviving any life or injury-threatening situation in civil aviation (FAA, 2003, Australian Civil Aviation Safety Authority (CASA), 2004), it is important for the national aviation industry to enhance the comprehensibility of safety briefing cards. Additionally, the design approach used in the study to create a mixture style was easily realized. Designers could adapt the new mixture style pictorials from existing all-real photo or all-illustration ones, which is low cost, high feasibility and worth to promote in markets.

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